Timing system for the Lunar Laser Ranging station at HartRAO, South Africa: preliminary results

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Introduction & Instrumentation

HartRAO is currently developing a Lunar Laser Ranging station based on a 1 metre Cassegrain telescope donated by the Observatoire de la Côte d'Azur (OCA), France[1]. We report on current developments on the LLR timing system, which is based on a Microsemi 4380A rubidium clock.

Environmental conditions of the LLR timing system such as variation in temperature can affect clock frequency stability. The 4380A LLR timing system (Fig. 1) requires a thermally stable environment to minimize thermally induced errors.

Figure 1. The rubidium 4380A timing system for the new LLR station at HartRAO. The system is currently being tested for short and long term stability against Hydrogen masers.

Figure 2. The GPS-702-GG Novatel dual-frequency antenna installed on top of the building at HartRAO. The 4380A timing system uses this GPS antenna to update the rubidium clock.

Table 1. HartRAO 4380A rubidium clock specifications. It is steered by GPS, with a timing accuracy of less than 10 ns Root Mean Square (RMS).

Specification	Values
Allan Deviation (at 1 s)	6×10^{-13}
Frequency accuracy (at 1 day)	$<1\times 10^{-13}$
Frequency stability due to thermal effects	3×10^{-10} [0℃ to 50℃]
Phase Noise (at 1 Hz)	-110 dBc/Hz

Sub-centimetre ranging accuracy requires a timing system with picosecond accuracy. Table 1 provide specifications for our timing system, the 4380A timing system seems to meet our requirement of sub-centimetre ranging accuracy. This requirement only takes into account the capabilities of the timing system without other external factors, which include error contributions by the atmosphere, system calibration errors, etc., some of these are discussed in Munghemezulu et al[2].

Methods and Results

The short term frequency stability of the 4380A rubidium clock was measured by comparison – we used a frequency comparator (VCH-314) at 5 MHz, comparing our system's output with the EFOS28 maser output as a reference[3]. Our timing system's stability has been measured against the maser and maintains less than a picosecond Allan deviation over a period of 10^3 s (Fig. 3).

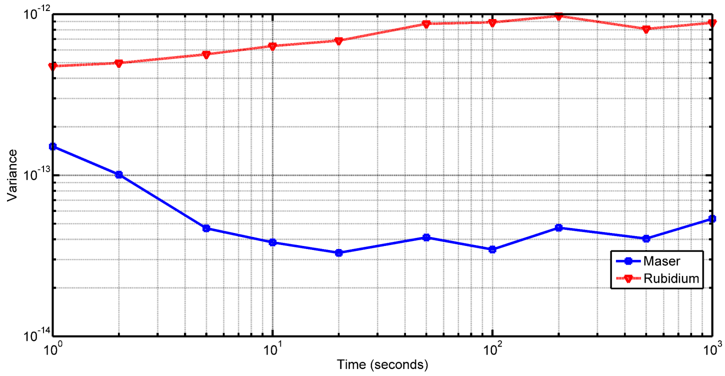

Figure 3. Short term stability of the rubidium clock measured against hydrogen maser clock. The rubidium clock has a sub-picosecond stability over 10^3 s period.

The LLR control room temperature is maintained by three air conditioning systems. The measured temperature variations are in the range of ~3ºC per day (Fig. 4). Since our timing system has a thermally-dependent frequency error of 3×10^{-10} between 0ºC and 50ºC, the control room temperature is maintained at a sufficient level to ensure optimal operation of our timing system.

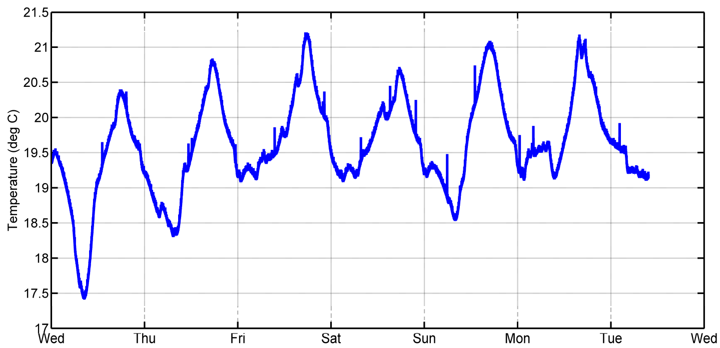

Figure 4. Temperature variation inside the LLR control room. The temperature of the control room is maintained by air condition cooling system. We can maintain the control room temperature to within ~3°C/day by an air condition system.

Conclusion

Initial results indicate that the 4380A timing system can achieve sub-picosecond Allan deviation in a 10^3 s period, and that the LLR control room exhibit temperature variations of ~3°C per day. Since the frequency stability of the 4380A is 3×10^{-10} between 0°C and 50°C, the current LLR thermal control system seems to be adequate to minimize thermally induced frequency errors during ranging. Our LLR normal data point accuracy, due to the timing reference system, is therefore anticipated to be a centimetre or less.

References

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